Topic 4.6 Waves Revision Booklet

ANSWERS AQA GCSE Physics 8463 · Foundation & Higher



Name _____ Class _____ Target grade _____

4.6
Waves

Work through a topic, then come back to it on the dates in your planner. Little and often beats one long cram.

Revise like a scientist

This booklet uses six revision techniques that research shows work best. Every activity is labelled with the technique it uses and the grade it targets.

Retrieval practice

Pulling ideas out of your memory makes them stick far better than re-reading. Brain dumps, quizzes and cover-and-recall tasks.

Spaced practice

Revisit each topic after 2 days, 1 week and 3 weeks. Forgetting a little, then remembering again, strengthens memory.

Interleaving

Mixed-topic questions train you to spot which idea a question needs, just like the real exam.

Dual coding

Words plus diagrams: graphs, ray diagrams and labelled apparatus give your memory two routes in.

Elaboration

Asking 'why?' and 'how?' and linking ideas together turns facts into understanding.

Worked examples

I do → We do → You do: study a full solution, finish a half-done one, then do one alone.

KEY

Grade pathways

GRADE 4

Secure the basics: recall definitions and units, pick the right equation from the equation sheet, and do one-step calculations.

GRADE 5

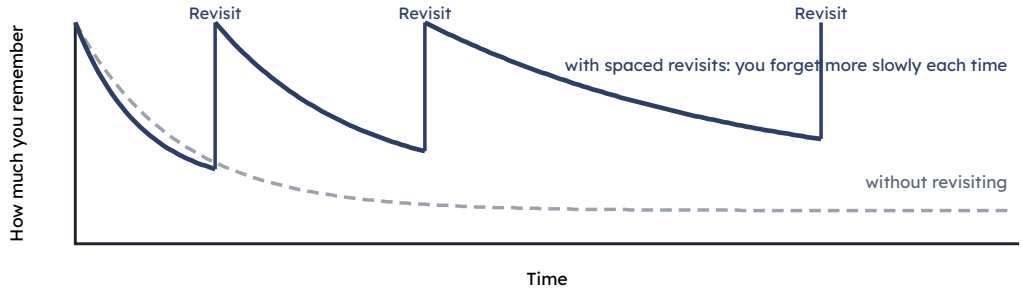
Rearrange equations, convert units, describe practicals and explain in two linked steps.

GRADE 7+

Multi-step calculations, evaluate methods and data, and write logical 6-mark answers.

SPACED PRACTICE DUAL CODING

Why spacing works



SPACED PRACTICE

My spaced revision planner

Write the date you'll do each session. Tick it off when it's done.

Topic	First go	+2 days	+1 week	+3 weeks	Before the mock
4.6 Waves					
Final review					

What's inside

Topic 6 · Waves (4.6)

6.1 Brain dump and checklist	4
6.2 Knowledge organiser (2 pages)	5
6.3 Cover, recall, check	7
6.4 Picture it: waves, the EM spectrum and lenses	8
6.5 I do, we do, you do: wave calculations	10
6.6 Why? How? Explaining waves	11
6.7 Required practicals 8, 9 and 10	12
6.8 Exam practice: Grade 4, 5 and 7+	14
6.9 Reflect and plan	16

Final review

Final review: mixed questions	17

ROUTINE

The routine for every page

1. Try it cold. Answer from memory first, without notes. Struggling a bit is good: it's what makes learning stick.

2. Check and correct. Mark it with the answer booklet in a different colour pen. Fix every mistake.

3. Come back later. Redo anything you got wrong on your next spaced session.

ONLINE

Use it with mrsullyphysics.com

Flashcards for retrieval practice: cards you get wrong come back until you get them right.

Quizzes and Aim higher for extra Grade 5+ and 7+ questions with mark schemes.

Animations to see the physics move (dual coding).

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Use the idea of wavefronts to explain why light changes direction when it enters a glass block at an angle. [4]

One side of the wavefront reaches the glass first

That side slows down first

The rest of the wavefront is still moving faster in air

So the wavefront changes direction, towards the normal

2 Grade 7+ A radio station broadcasts at a frequency of 100 MHz. Radio waves travel at 3×10^8 m/s. Calculate the wavelength. [3]

100 MHz = 100 000 000 Hz (1×10^8 Hz)

$\lambda = v \div f = 3 \times 10^8 \div 1 \times 10^8$

$\lambda = 3$ m

3 Grade 5 Explain the difference between specular and diffuse reflection. [2]

Specular: reflection from a smooth surface in a single direction

Diffuse: reflection from a rough surface, scattered in many directions

Brain dump and checklist

RETRIEVAL PRACTICE | GRADE 4 | GRADE 5 | GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about waves. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: transverse/longitudinal? · v = fλ? · EM spectrum order? · uses and dangers? · refraction? · lenses? · black body? · ultrasound? · seismic waves?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Describe transverse and longitudinal waves with examples	○	○	○	○	○	○
Define amplitude, wavelength, frequency and period; use v = fλ and T = 1/f	○	○	○	○	○	○
Describe how to measure wave speed in a ripple tank and on a string (RP8)	○	○	○	○	○	○
Describe reflection, refraction and the reflection/refraction practical (RP9, Physics only)	○	○	○	○	○	○
Explain refraction using wavefronts (Higher)	○	○	○	○	○	○
Recall the EM spectrum in order, with uses and dangers	○	○	○	○	○	○
Explain ultrasound and seismic waves (Physics only, Higher)	○	○	○	○	○	○
Use magnification and draw lens ray diagrams (Physics only)	○	○	○	○	○	○
Explain colour and filters (Physics only)	○	○	○	○	○	○
Describe the infrared practical and black body radiation (RP10)	○	○	○	○	○	○

Extra practice

Retrieval · answers in the answer booklet

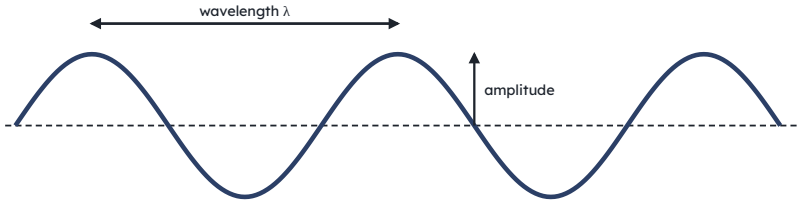
1 Which EM wave is used to communicate with satellites? [1]

A Microwaves **B** X-rays **C** Gamma **D** Ultraviolet

A: Microwaves. Microwaves pass through the atmosphere easily.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

TRANSVERSE AND LONGITUDINAL WAVES



Transverse: oscillations perpendicular to the direction of energy transfer (e.g. light, water ripples)



direction of energy transfer

Longitudinal: oscillations parallel to the direction of energy transfer (e.g. sound)

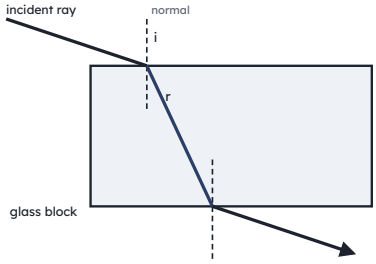
THE ELECTROMAGNETIC SPECTRUM

wavelength increases

Radio	Microwave	Infrared	Visible	Ultraviolet	X-ray	Gamma
TV, radio	satellites, cooking	heaters, IR cameras	fibre optics	tanning, energy-efficient lamps	medical imaging	medical imaging and treatment

frequency increases · shaded = can harm body tissue (UV, X-rays, gamma)

REFRACTION



Entering glass: slows down, changes direction towards the normal

Leaving glass: speeds up, changes direction away from normal

Measure angles from the normal

KEY EQUATIONS: ALL GIVEN ON THE PHYSICS EQUATIONS SHEET IN THE EXAM

Equation	Quantities and units	Watch out
$v = f\lambda$	wave speed (m/s), frequency (Hz), wavelength (m)	MHz → Hz: × 10^6
$T = 1 \div f$	period (s), frequency (Hz)	Period: time for one wave
magnification = image height ÷ object height	no units (Physics only)	Same units top and bottom

EM WAVES

Transverse; all travel at the same speed (3×10^8 m/s) in a vacuum; transfer energy from a source to an absorber.
Ionising: UV, X-rays, gamma: can damage cells; UV causes skin ageing and skin cancer risk.
Radiation dose is measured in sieverts (Sv).

TURN OVER

Key words, misconceptions, required practicals and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION GRADE 4 GRADE 5 GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

Transverse: oscillations are perpendicular to the direction of energy transfer.
Longitudinal: oscillations are parallel to the direction of energy transfer; compressions and rarefactions.
Amplitude: the maximum displacement of a point on a wave away from its undisturbed position.
Wavelength: the distance from a point on one wave to the equivalent point on the adjacent wave.
Frequency: the number of waves passing a point each second (Hz).
Refraction: a change in direction when a wave changes speed crossing a boundary.
Perfect black body (PO): an object that absorbs all of the radiation incident on it; the best possible emitter.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× Water travels along with the wave.	✓ Waves transfer energy, not matter.
× Sound travels through a vacuum.	✓ Sound needs particles to vibrate.
× All EM waves are dangerous.	✓ Only UV, X-rays and gamma rays harm body tissue; X-rays and gamma rays are ionising.
× Light bends when it goes into glass.	✓ Light travels in straight lines. It changes direction at the boundary because its speed changes.

RP8: WAVES

Aim: Make observations to identify suitable apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid (a stretched string), and take appropriate measurements.
Change: Frequency (string) · **Measure:** Wavelength · **Control:** Water depth (ripple tank), tension and string length
Must include: Take measurements for both the ripple tank and waves in a solid (string); Justify why the apparatus is suitable; Measure across several wavelengths and divide; Determine frequency by counting over a set time or from the signal generator.
Common mistake: Measuring one wavelength only.

RP9: LIGHT (REFLECTION AND REFRACTION) (PO)

Aim: Investigate the reflection of light by different types of surface and the refraction of light by different substances.
Change: Angle of incidence · **Measure:** Angle of reflection or refraction · **Control:** Ray box, block material, width of ray
Must include: Test reflection from different types of surface; Test refraction in different substances; Draw a normal; Measure angles from the normal with a protractor.
Common mistake: Measuring angles from the surface instead of the normal.

RP10: RADIATION AND ABSORPTION

Aim: Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.
Change: Type of surface · **Measure:** Infrared emitted (detector reading) · **Control:** Water temperature, distance from detector
Must include: Investigate absorption as well as emission; Same water temperature for all faces; Same distance from the detector; Record a reading for each surface.
Common mistake: Drawing a line graph for categoric data.

AIM FOR GRADE 7+

- Standard form and unit prefixes in $v = f\lambda$ (MHz, kHz, 3×10^8 m/s).
- Explain refraction using wavefronts (Higher).
- Echo questions: halve the total distance (Physics only, Higher).

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5

Equation sheet skills: which equation, which unit?

Every equation is on the Physics Equations Sheet, but it won't tell you which one a question needs or what unit the answer has. Cover the knowledge organiser and fill in the table. Redo it on another day.

Situation	Which equation?	Unit of the answer	Redo 1 ✓/ ×	Redo 2 ✓/ ×
Speed of a sound wave from its frequency and wavelength	**$v = f \lambda$**	**m/s**		
Period of a water wave from its frequency	**$T = 1 \div f$**	**s**		
Wavelength of a radio wave ($v = 3 \times 10^8$ m/s)	**$\lambda = v \div f$**	**m**		
Distance to a cliff from an echo time	**$s = v\ t$ (then ÷ 2)**	**m**		
Magnification of an image (Physics only)	**magnification = image height ÷ object height**	**no unit**		
Frequency of a wave from its period	**$f = 1 \div T$**	**Hz**		

RETRIEVAL PRACTICE | GRADE 4 | GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. In a transverse wave the oscillations are **perpendicular** to the direction of energy transfer.
2. The number of waves passing a point each second is the **frequency**.
3. All electromagnetic waves travel at the same **speed** in a vacuum.
4. When light enters glass at an angle it slows down and changes **direction** towards the normal.
5. Sound waves are **longitudinal** waves.

ELABORATION | GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. radio · microwave · sound · infrared

Sound: it isn't an electromagnetic wave (it's longitudinal and needs a medium).

2. amplitude · wavelength · frequency · density

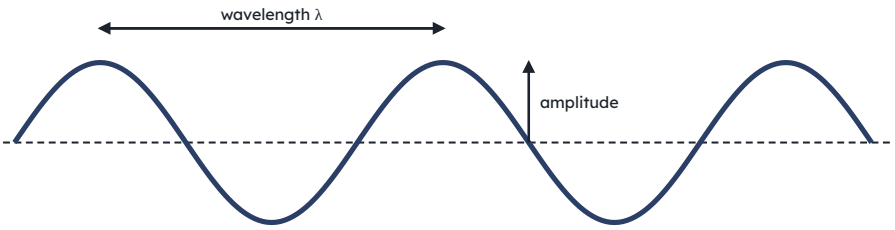
Density: it isn't a property of a wave.

3. gamma · X-ray · ultraviolet · radio

Radio: the others (gamma, X-rays, UV) can harm body tissue.

DUAL CODING GRADE 4 GRADE 5

Label the waves



Transverse: oscillations perpendicular to the direction of energy transfer (e.g. light, water ripples)

a On the transverse wave, label the amplitude and one wavelength. [2]

Amplitude: rest position to crest. Wavelength: crest to crest.

b Give one example of a transverse wave and one of a longitudinal wave. [2]

Transverse: light / water ripples / any EM wave

Longitudinal: sound / P-waves

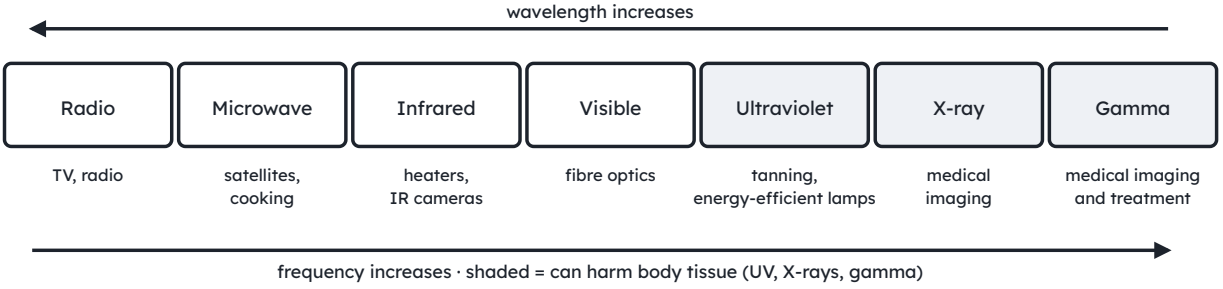
c Describe the movement of air particles as a sound wave passes. [2]

They oscillate backwards and forwards (parallel to the direction of travel);

the particles don't travel with the wave.

DUAL CODING GRADE 4 GRADE 5

The electromagnetic spectrum



a Which EM wave has the longest wavelength? [1]

Radio waves

b Give one use and one danger of ultraviolet. [2]

Use: energy-efficient lamps / sun tanning / security marking

Danger: skin ages prematurely and risk of skin cancer

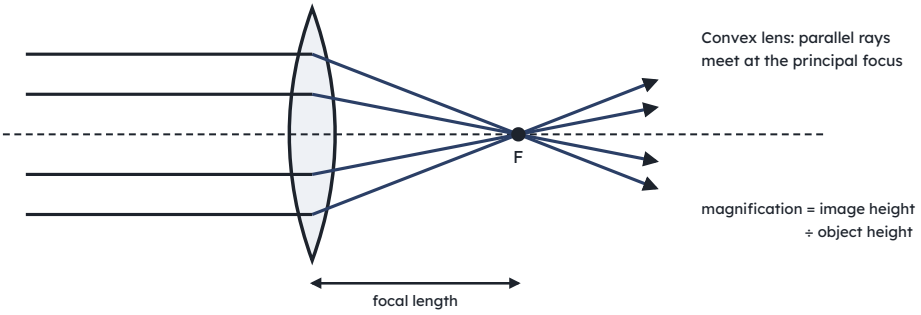
c Why are X-rays used to image bones? [2]

X-rays pass through soft tissue

but are absorbed by bone.

DUAL CODING GRADE 5 GRADE 7

Lenses (Physics only)



a What type of lens is drawn? How do you know? [1]

Convex: it brings parallel rays to a focus.

b An image is 6 cm tall and the object is 2 cm tall. Calculate the magnification. [2]

6 ÷ 2

= 3

c Is the image from a magnifying glass real or virtual? [1]

Virtual (and upright, magnified).

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A pulse of ultrasound is reflected from an organ. The echo returns after 1.2×10^{-4} s. Ultrasound travels at 1500 m/s in tissue. Calculate how far the organ is below the skin. [3]

Distance travelled = v × t = $1500 \times 1.2 \times 10^{-4} = 0.18$ m

This is there and back

Depth = 0.09 m (9 cm)

2 Grade 7+ White light passes through a green filter onto a red object. Explain what colour the object appears. [3]

The filter only transmits green light (absorbs other colours)

The red object reflects red light and absorbs green

No light is reflected, so the object appears black

3 Grade 5 Give one use of microwaves and one use of infrared. [2]

Microwaves: satellite communications or cooking food

Infrared: electric heaters, cooking or infrared cameras

I do, we do, you do

WORKED EXAMPLES · GRADE 4 · GRADE 5

Wave speed

I do (worked example)

A wave has f = 200 Hz, λ = 1.7 m. Calculate v.

1. v = f λ
2. v = 200 × 1.7
3. **v = 340 m/s**

We do (finish it)

A ripple: f = 4 Hz, λ = 0.05 m.

1. v = 4 × ___ **0.05**
2. v = ___ m/s **0.2**

You do

Sound at 330 m/s, f = 660 Hz. Calculate λ.

λ = v ÷ f

= 330 ÷ 660

= 0.5 m

WORKED EXAMPLES · GRADE 5 · GRADE 7

Period and frequency

I do (worked example)

A wave has a period of 0.04 s. Calculate f.

1. f = 1 ÷ T
2. f = 1 ÷ 0.04
3. **f = 25 Hz**

We do (finish it)

f = 50 Hz. Calculate T.

1. T = 1 ÷ ___ **50**
2. T = ___ s **0.02**

You do

T = 0.5 s, λ = 3 m. Calculate v.

f = 1 ÷ 0.5 = 2 Hz

v = 2 × 3

= 6 m/s

WORKED EXAMPLES · GRADE 7

Echoes (Grade 7+)

1 A ship sends an ultrasound pulse to the sea bed. The echo returns after 0.8 s. Sound travels at 1500 m/s in sea water. Calculate the depth of the sea. (Physics only) [3]

Distance travelled = 1500 × 0.8 = 1200 m

This is there and back,

so depth = 1200 ÷ 2 = 600 m

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A ship sends an ultrasound pulse to the seabed. The echo returns 0.4 s later. Sound travels at 1500 m/s in water. Calculate the depth. [3]

Distance = speed × time = 1500 × 0.4 = 600 m

This is there and back

Depth = 600 ÷ 2 = 300 m

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

1 Explain why light changes direction when it passes from air into water at an angle.

Grade 4–5 starter: "Light slows down when it enters water, so…"

Light travels more slowly in water than in air.

One side of the wavefront enters the water first and slows down first,

Grade 7+ extension: "Use the idea of a wavefront:…"

while the rest is still travelling faster in the air.

So the wavefront changes direction, towards the normal.

2 Explain why a red object looks black in blue light. (Physics only)

Grade 4–5 starter: "A red object reflects only red light, so…"

A red object reflects red light and absorbs all other colours.

Blue light contains no red,

Grade 7+ extension: "Link to what reaches your eyes:…"

so the blue light is absorbed and none is reflected,

so no light reaches your eyes from the object and it looks black.

3 Explain why the Earth's temperature depends on the radiation it absorbs and emits. (Physics only)

Grade 4–5 starter: "The Earth absorbs radiation from the Sun and…"

The Earth absorbs radiation from the Sun and emits radiation into space.

If it absorbs radiation faster than it emits it, its temperature rises.

Grade 7+ extension: "Link to balance:…"

If the rates are equal, its temperature stays constant.

Greenhouse gases reduce the rate infrared escapes, so the temperature rises.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "Sound travels faster than light." [2]

False: light travels at 3×10^8 m/s in a vacuum;

sound travels at about 330 m/s in air.

5 "Microwaves are ionising." [1]

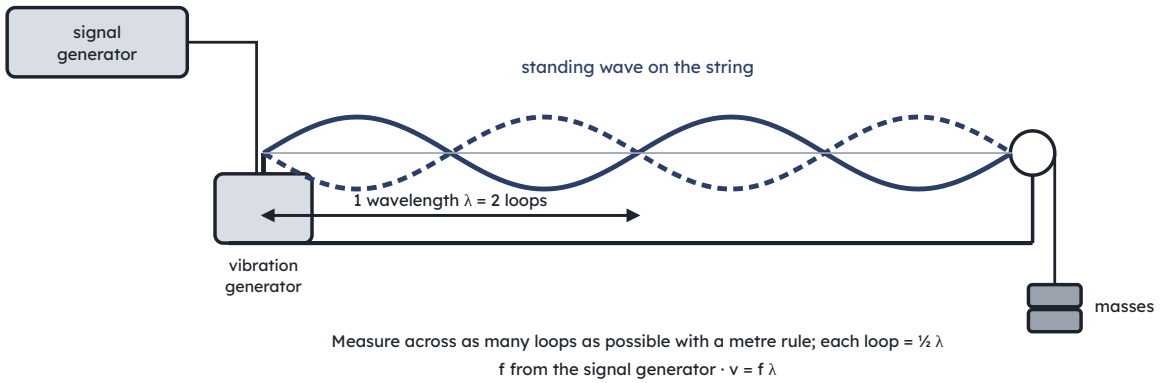
False: microwaves are not ionising; X-rays and gamma rays are.

RP8: waves on a string

WORKED EXAMPLES | GRADE 5 | GRADE 7

RP8: waves on a string

A string is attached to a vibration generator. The frequency is changed and the wavelength of the standing wave is measured.



Measure across as many loops as possible with a metre rule; each loop = ½ λ
f from the signal generator · v = f λ

f (Hz)	λ (m)	v (m/s)
20	1.20	**24**
30	0.80	**24**
40	0.60	**24**
60	0.41	**24.6**

a Complete the table using v = f λ. [2]

24, 24, 24, 24.6 m/s

b What do the results show about wave speed on the string? [1]

It stays (about) the same when the frequency changes.

c Describe how to measure the wavelength of a standing wave accurately. [2]

Measure across as many half-wavelengths (loops) as possible with a metre rule,

then divide to find one wavelength (each loop = half a wavelength).

d Give one way to measure the speed of ripples in the ripple tank. [2]

Measure λ across 10 waves ÷ 10; count waves passing a point in 10 s ÷ 10 to get f;

then v = f λ.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Describe the difference between transverse and longitudinal waves, giving an example of each. [3]

Transverse: oscillations perpendicular to the direction of energy transfer

Longitudinal: oscillations parallel to the direction of energy transfer

Examples, e.g. light or water ripples (transverse); sound (longitudinal)

Required practicals 8, 9 and 10 (continued)

RETRIEVAL PRACTICE | ELABORATION | GRADE 4 | GRADE 5 | GRADE 7

RP9 and RP10: refraction data and infrared

Part 1: a ray enters a glass block. Part 2: a Leslie cube.

Angle of incidence (°)	0	20	40	60
Angle of refraction (°)	0	13	25	35

a Describe the pattern. [2]

The angle of refraction increases as the angle of incidence increases;

it is always smaller (the light changes direction towards the normal).

b Why is there no change of direction at 0°? [1]

The ray travels along the normal, so the whole wavefront slows down at the same time.

Surface	Infrared detector reading
Matt black	92
Shiny black	80
Matt white	45
Shiny silver	18

c Which surface is the best emitter of infrared? (RP10) [1]

Matt black

d Why must the detector be the same distance from each surface? [1]

Distance affects the reading (control variable), so it's a fair test.

e Suggest why kettles are often shiny. [1]

Shiny surfaces are poor emitters, so less energy is transferred by infrared radiation.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Name the three types of electromagnetic radiation that can harm body tissue, and give one hazard they can cause. [3]

Ultraviolet

X-rays and gamma rays

Hazard: e.g. skin cancer or premature skin ageing (UV); gene mutation or cancer (X-rays, gamma)

2 Grade 5 Calculate the period of a wave with a frequency of 50 Hz. [2]

T = 1 ÷ f = 1 ÷ 50

T = 0.02 s

Exam practice

GRADE RADE 4

Secure the basics

1 What is the unit of frequency? [1]

Hertz (Hz)

2 Name the EM wave used in TV remote controls. [1]

Infrared

3 What do all waves transfer? [1]

Energy (not matter)

4 Give one use of microwaves. [1]

Satellite communications / cooking food

5 What is the normal? [1]

A line at 90° to the surface where the ray hits it.

GRADE RADE 5

Apply and rearrange

6 Calculate the frequency of a radio wave with wavelength 1500 m. ($v = 3 \times 10^8$ m/s) [2]

$f = v \div \lambda = 3 \times 10^8 \div 1500$

$= 200\,000$ Hz (2×10^5 Hz)

7 Explain why gamma rays are dangerous to the human body. [2]

They are ionising,

so they can damage cells and DNA (risk of cancer).

8 State the law of reflection. [1]

Angle of incidence = angle of reflection.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A convex lens forms an image 4.5 cm tall of an object 1.5 cm tall. The image forms on the other side of the lens. Calculate the magnification and state whether the image is real or virtual. [3]

Magnification = image height ÷ object height = 4.5 ÷ 1.5

Magnification = 3 (no units)

The image is real, because the rays actually meet on the other side of the lens

2 Grade 5 A wave has a frequency of 4 Hz and a wavelength of 0.5 m. Calculate its speed. [2]

$v = f\lambda = 4 \times 0.5$

$v = 2$ m/s

GRADE RADE 7+

Stretch

9 Explain how P-waves and S-waves provide evidence for the structure of the Earth. (Physics only) [4]

S-waves are transverse and cannot travel through liquids.

They are not detected on the opposite side of the Earth (S-wave shadow zone),

so the outer core must be liquid.

P-waves change speed and direction (refract) at the boundaries, showing layers of different density.

10 Describe how to investigate the refraction of light through a glass block. [6]

Place a glass block on paper and draw round it; draw a normal at 90° to one face.

Shine a ray from a ray box at the block at a measured angle of incidence.

Mark the ray entering and leaving with crosses; remove the block and join the points.

Measure the angle of refraction from the normal with a protractor.

Repeat for a range of angles of incidence (e.g. 10° to 70°).

Do it in a darkened room with a thin ray to reduce errors; compare different materials if required.

Total: _____ / 20

RETRIEVAL PRACTICE SPACED PRACTICE GRADE 4

Quick-fire retrieval: Waves

Cover everything. Answer in under 3 minutes. Redo it on your next spaced session.

1 Speed of EM waves in a vacuum?

3×10^8 m/s

2 Longitudinal wave example?

Sound

3 Wave used for imaging inside the body without ionising?

Ultrasound

4 Unit of wavelength?

Metre (m)

5 Colour of a white object in red light?

Red

6 Highest frequency EM wave?

Gamma

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ An object 0.5 cm tall is viewed through a magnifying glass with a magnification of 12. Calculate the height of the image. [2]

Magnification = image height ÷ object height

Image height = 12 × 0.5 = 6 cm

Reflect and plan

METACOGNITION

Re-rate yourself

Go back to the checklist at the start of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, standard form		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION

Two things I'm now confident about

_____

_____

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging equations → redo the Grade 7+ questions and use the website's Aim higher section.'

_____

_____

_____

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner at the front: +2 days, +1 week, +3 weeks.

Extra practice

Retrieval · answers in the answer booklet

1 Fill the gap: A perfect black body _____ all of the radiation incident on it. [1]

absorbs. It doesn't reflect or transmit any radiation (Physics only).

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5 | GRADE 7

Final review: test yourself on the whole topic

Do these without your notes, a week after finishing the booklet. Mark them with the answer booklet and add any you got wrong to your 'still to learn' list on the reflect page.

Each question shows its target grade. Aim to get every Grade 4 and 5 question right before moving on to Grade 7+.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Use the idea of wavefronts to explain why light changes direction when it enters glass at an angle. [3]

Light slows down when it enters glass

One side of each wavefront reaches the glass first and slows down

The rest of the wavefront keeps moving faster, so the wavefront changes direction (towards the normal)

2 Grade 7+ A radio station broadcasts at 1.5 MHz. Calculate the wavelength. (speed of EM waves = 3×10^8 m/s) [3]

1.5 MHz = 1.5×10^6 Hz

$\lambda = v \div f = 3 \times 10^8 \div 1.5 \times 10^6$

$\lambda = 200$ m

3 Grade 7+ Explain why X-rays are useful for taking images of bones, and why their use is limited. [4]

X-rays are absorbed by bone but pass through soft tissue

So bones show up as shadows on the detector

X-rays are ionising and can damage cells / cause cancer

So exposure is kept low and staff stand behind screens; benefits must outweigh risks

4 Grade 7+ Use wavefronts to explain why light changes direction towards the normal when it enters glass at an angle, but does not change direction when it enters along the normal. [4]

Light slows down when it enters glass

At an angle, one end of each wavefront enters the glass and slows down first, while the rest is still faster

So the wavefront changes direction, towards the normal

Along the normal, the whole wavefront slows down at the same time, so it doesn't change direction